EFFECT OF Al DOPING ON THE MICROSTRUCTURE AND ELECTRICAL TRANSPORT PROPERTIES OF YBCO SUPERCONDUCTOR

MUHAMMAD IRFAN BIN IZHAM

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SUPERVISORS' DECLARATION

I hereby declare that I have checked the thesis and in my opinion, this thesis is adequate in terms of scope and quality for the award of the degree of Bachelor of Applied Science (Honours) Material Technology.

Signature

Name of Supervisor : Dr Muhammad Hafiz b Mazwir

Position : SENIOR LECTURER

Date : 6/1/2017

STUDENT'S DECLARATION

I hereby declare that the work in this thesis is my own except for quotations and summaries which have been duly acknowledged. The thesis has not been accepted for any degree and is not concurrently submitted for award of other degree.

Signature	:	
Name	:	Muhammad Irfan b Izham
ID Number	:	SC13037
Date	:	

DEDICATION

My biggest dedication goes to my families; Izham, Shahida, Ilya, Isfahan and Imran for their supporting commends, their understanding towards my research and many more.

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ABSTRACT

Superconductor used is $YBa_2Cu_3O_7$ (YBCO) with addition dopant element of Aluminium (Al). The Al_2O_3 doping is used to study the microstructure and electrical transport properties of YBCO superconductor. Process involved in preparation of YBCO superconductor is by using solid state reaction method. The superconductors were prepared with different composition of aluminium oxide doping which are 0.01 wt%, 0.02 wt%, 0.03 wt%, 0.04 wt%. The samples were tested with four analyses which are for phase formation; X-Ray Diffractometer (XRD) is used, for microstructure; Scanning Electron Microscopy (SEM) is used, for critical current; Four Point Probe is used, and for Meissner Effect of superconductors. The results obtained for XRD can be conclude that YBCO compound having an orthorhombic structure which shows superconducting behaviour. For SEM results, the microstructure obtain is almost the same with constant or pure YBCO superconductor although doping process were done to the samples this is due to the concentration of magnetic nanoparticles were too small to act as impurity and to cause porous structure. Next, for four point probe testing, the result obtained is the resistance value = 0 Ω when cooled at critical temperature, T_c but some errors might occur that causes some changes to the results. Lastly, Meissner Effect test shows that the critical temperature of YBCO superconductor is high when addition of Al_2O_3 element is added, compared to pure YBCO superconductor.

ABSTRAK

Superkonduktor yang digunakan adalah $YBa_2Cu_3O_7$ (YBCO) dengan elemen tambahan dopan daripada Aluminium (Al). Al_2O_3 doping digunakan untuk mengkaji mikrostruktur dan pengangkutan elektrik sifat YBCO superkonduktor. Proses yang terlibat dalam penyediaan YBCO superkonduktor adalah dengan menggunakan kaedah tindak balas keadaan pepejal. Superkonduktor telah disediakan dengan komposisi yang berbeza daripada aluminium oksida doping yang 0.01 %berat, 0.02 %berat, 0.03 %berat, 0.04 %berat. Sampel diuji dengan empat analisis iaitu bagi pembentukan fasa; X-ray Pembelauan (XRD) digunakan, untuk mikrostruktur; Mikroskop Pemindai Elektron (SEM) digunakan, untuk suhu kritikal; empat mata siasatan digunakan, dan untuk Kesan Meissner superkonduktor. Keputusan yang diperolehi untuk XRD boleh menyimpulkan bahawa sebatian YBCO mempunyai struktur otorombik yang menunjukkan tingkah laku superkonduktor. Untuk keputusan SEM, mikrostruktur mendapatkan hampir sama dengan pemalar atau tulen superkonduktor YBCO walaupun proses doping telah dilakukan untuk sampel ini adalah disebabkan oleh kepekatan nanopartikel magnet terlalu kecil untuk bertindak sebagai bendasing dan menyebabkan struktur berliang. Seterusnya, untuk empat mata siasatan ketika, keputusan yang diperolehi adalah nilai rintangan = 0 Ω apabila disejukkan pada suhu kritikal, T_c tetapi beberapa kesilapan mungkin berlaku yang menyebabkan beberapa perubahan kepada keputusan. Akhir sekali, ujian Kesan Meissner menunjukkan bahawa suhu genting superkonduktor YBCO adalah tinggi apabila penambahan Al_2O_3 elemen ditambah, berbanding YBCO superkonduktor tulen.

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LIST OF SYMBOLS

T_c	-	Critical Temperature
%	-	Percent
J_c	-	Critical Current Density
λ	-	Penetration Depth
ξ	-	Coherence Length
ϕ	-	Permit Magnetic Flux
B	-	Magnetic Field
B_{c1}	-	Lower Critical Magnetic Field
B_{c2}	-	Upper Critical Magnetic Field
I	-	Current
V	-	Voltage
Ω	-	Resistance
wt.%	-	Weight Percentage
2θ	-	Bragg Angle

LIST OF ABBREVIATIONS

Al_2O_3	-	Aluminium Oxide
$BaCO_3$	-	Bariun Carbonate
BCS	-	Bardeen Copper Schrieffer
BSCCO	-	Bismuth Strontium Calcium Copper Oxide
CH_3CH_2OH	-	Ethanol
CH_3COCH_3	-	Acetone
CuO	-	Copper (II) Oxide
EDX	-	Energy Dispersive X-ray
FESEM	-	Field Emission Scanning Electron Microscope
SEM	-	Scanning Electron Microscopy
XRD	-	X-ray Diffraction
Y123	-	Yttrium Barium Cuprate
Y_2O_3	-	Yttrium Oxide
YBCO	-	Yttrium Barium Copper Oxide
$YBa_2Cu_3O_7$	-	Yttrium Barium Copper Oxide
$YBa_2Cu_{3-X}Al_XO_7$	-	Yttrium Barium Copper Oxide Al Doped

CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION

Superconductors are materials that permit current to stream with no resistance. They are additionally utilized as immaculate diamagnets when presented to moderate magnetic fields. High temperature superconductor has an incredible potential to be created for high vitality transport applications. Nonetheless, the flux pinning capacity and intergrain link should be enhanced keeping in mind the end goal to reduce the quick decay of the critical current density J_c at high temperature and in magnetic fields.

The electrical resistivity of numerous metal and alloys drops abruptly to zero when the sample is cooled to adequate temperature, regularly in the fluid helium temperature range. This marvel is called superconductivity and was initially seen by Kamerlingh Onnes in 1911. At critical temperature, T_c the example experiences a phase transition from a state of ordinary electrical resistivity to superconducting state. In the superconducting state the dc electrical resistivity is zero, or so close to zero that electrical current have been seen to flow without constriction in superconducting ring.

Other vital property of superconductors was found in 1933 by Meissner and Ochsenfeld. One would expect, because of the ideal conductivity, that magnetic flux ought to be prohibited from entering a superconductor, additionally it was found that flux was ousted from the material as it was cooled through its critical temperature. This marvel is called 'Meissner' effect. Ginzburg–Landau hypothesis was created in 1950, which characterizes two parameters which are the London magnetic field penetration depth *(λ)* and the superconducting coherence length *(ξ)*. In 1957, BCS hypothesis was produced to clarify the superconductivity.

There are two types of superconductors which are Type I and Type II. In Type I, superconductors that has single critical field B_c, superconductivity is demolished by method for a first order phase transition when the nature of the associated field rises above H_c. This type of superconductivity regularly appears in metals, e.g. aluminum, lead, and mercury. Type II superconductor has two critical field, B_{c1} and higher critical field, B_{c2}. The lower critical field B_{c1} happens when appealing flux vortices invade the material however the material stays superconducting outside of these microscopic vortices. Exactly when the vortex thickness gets the opportunity to be excessively sweeping, the entire material gets, making it impossible to be non-superconducting, this identifies with the second, higher critical field B_{c2}. In a type II superconductor, the understandability length is smaller than the passage significance. Type II superconductors are ordinarily made of metal mixes or complex oxide ceramic generation. All high temperature superconductors are type II superconductors. Ginzburg-Landau proposes that for Type-I; $\frac{\lambda}{\xi} < \frac{1}{\sqrt{2}}$ while for Type-II; $\frac{\lambda}{\xi} > \frac{1}{\sqrt{2}}$.

The superconductor utilized as a part of this study is a type II superconductor YBCO ($YBa_2Cu_3O_7$) which was found by Maw-Kuen Wu and Chu Ching-Wu in 1987. YBCO has T_c higher than the breaking point of fluid nitrogen. A few nanoparticles have been included $YBa_2Cu_3O_7$ superconductor to go about as pinning centers with a specific end goal to enhance flux pinning capacity. As indicated by Lyuksyutov (1999) nanoparticles with size bigger than superconducting coherence length, ξ and smaller than London magnetic field penetration depth, λ of YBCO have been recommended to build J_c.

Figure 1.1 *Type I superconductor*

(Sources: hyperphysics.phy-astr.gsu.edu)

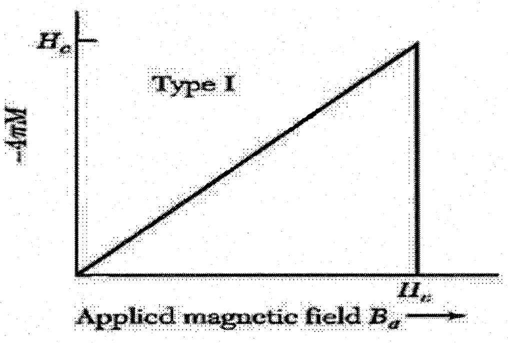
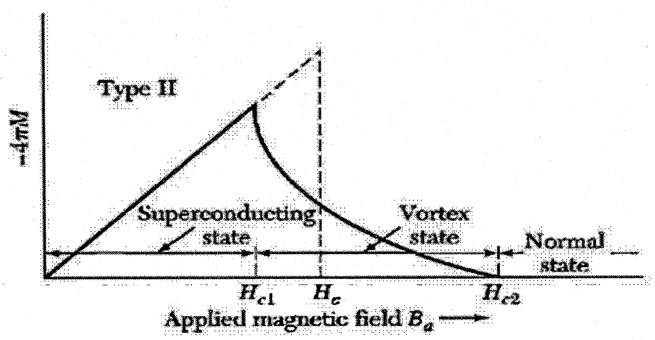


Figure 2 *Type II superconductor*

(Sources: hyperphysics.phy-astr.gsu.edu)



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